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(54) **TURBIDITY SENSOR AND METHOD FOR MEASURING TURBIDITY**

TRÜBUNGSSENSOR UND VERFAHREN ZUR MESSUNG VON TRÜBUNG

CAPTEUR DE TURBIDITÉ ET MÉTHODE DE MESURE LA TURBIDITE

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(73) Proprietor: **Process Instruments (UK) Limited**
Burnley, Lancashire BB12 0BT (GB)

(72) Inventors:

- **RIDING, Mike**
Burnley BB12 0BT (GB)
- **TRACEY, Craig**
Burnley BB12 0BT (GB)

(74) Representative: **Appleyard Lees IP LLP**

15 Clare Road
Halifax HX1 2HY (GB)

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Description**FIELD**

5 **[0001]** The disclosure relates to a turbidity sensor and method of measuring turbidity.

BACKGROUND

10 **[0002]** Turbidity is commonly used as a measure of water quality and gives an indication of how clean water is. It is commonly measured by illuminating a sample with a light source and measuring the response through the sample by a turbidity sensor. The turbidity sensor measures the amount of light scatter in the sample by the particles within the sample. Although a high particle concentration generally results in a high scattered signal, high particle concentrations can also give lower scattered signals once absorption becomes dominant and the light is attenuated.

15 **[0003]** When a turbidity measurement is made, the signal produced by the detector is composed of two components; the signal due to the scattered light through the sample and the signal due to the background light. Therefore, traditionally any background light must be subtracted from the total measured signal in order to isolate the actual output from the light source. When measurements are conducted in an uncontrolled environment, the background radiation will vary over time which means that traditionally the background radiation must be subtracted each time a measurement is taken. This is time consuming and laborious. Variations in background light will cause the result of the measurement to change, thus changing the apparent turbidity of a sample. At low levels, the background light can form a significant part of the total measured signal. The effect of background variation becomes even more significant if there is a difference between the background light when a calibration is made to when the measurement is made. The need to account for background radiation is inconvenient and is one of the reasons that makes calibration of instruments for turbidity measurements difficult. Furthermore, many calibration procedures require a measurement to be made with a calibration sample that is as close to 0 NTU (nephelometric turbidity unit, the unit of measurement of turbidity) as possible (pure water is around 0.018 NTU). However, such a sample is difficult to obtain and the measurement of such a sample will still be significantly affected by the background light levels.

25 **[0004]** It is therefore desirable to provide a turbidity sensor and method of measuring turbidity that removes the need to account for background radiation. Therefore an alternative solution to accurately collecting turbidity measurements is desired. A more convenient solution that provides a high level of performance is advantageous in order to achieve an accurate and fast acquisition of data collection. Ultimately, the aim is to provide a better turbidity sensor and method that is more user-friendly in order to overcome the disadvantages and drawbacks associated with conventional turbidity sensors.

30 **[0005]** In the background art, DE 10 2009 002 145 B3 Bosch Siemens describes measuring voltages that are generated in a light receiver for two current-strengths of a light-emitting diode. The voltage-current characteristic is calculated with an equation for correcting turbidity measurement.

35 **[0006]** WO 2001/29541 A1 Hedges et al relates to a device for measuring both the colour and turbidity of a liquid sample. US 2011/0273705 A1 Rao et al describes a sensing system that can measure both chlorophyll concentration and turbidity. US 2010/225920 A1 describes a nephelometric turbidity sensor comprising an additional reference optical detector for monitoring the intensity of the light source, wherein the sensor is designed to physically reject ambient light from entering the optical detectors.

SUMMARY

45 **[0007]** According to the present invention there is provided a turbidity sensor and method of measuring turbidity as set forth in the appended claims. Other features of the invention will be apparent from the dependent claims, and the description which follows.

50 **[0008]** According to the disclosure, a method of measuring turbidity is provided. The method includes conducting an optical test on a control fluid with known turbidity and repeating the optical test on a sample fluid with unknown turbidity. Each time, the optical test may be run under the same conditions or different conditions. For example, the optical test points for the control fluid be the same or different to the optical test points for the sample fluid. The optical test comprises the emission of a plurality of optical signals from an emitter toward the fluid. The emitter may be a light source such as an LED (light emitting diode) or a plurality of LEDs (i.e. an array of LEDs). The optical signal may be a collimated optical signal, which is collimated by a collimating tube. Each optical signal has a different optical setting amongst a particular optical characteristic. For example, the optical characteristic may be light intensity and the optical setting may be a particular light intensity. For each optical signal a reference signal and a fluid signal is captured. The reference signal is captured by detecting an optical response of the optical signal received by a first optical detector before the optical signal has entered the fluid. Therefore, the first optical detector and emitter may be sealed from the fluid by a fluid barrier.

The fluid barrier may be a window, such as a sapphire window. The first optical detector may be in the optical path of the emitter. Preferably, the first optical detector is in direct view of the emitter. That is, said first optical detector may be in line of sight of the emitter. Alternatively, the first optical detector may receive an indirect optical signal. That is, the optical signal may be reflected from the fluid barrier (i.e. a sapphire window). The fluid barrier may be positioned at an outlet of a collimating tube, wherein the emitter is interposed between the tube outlet the first optical detector. The fluid signal is captured by detecting an optical response of the optical signal received by a second optical detector in indirect view of the emitter. That is, said second optical detector may not be in line of sight of the emitter. Once the reference and fluid signals have been captured, the method includes determining a calibration factor of the turbidity sensor. By repeating the optical test for the sample fluid and collecting the reference and fluid signals from the sample fluid at a plurality of optical signals that may be different from the control fluid test, the turbidity of the sample fluid is determined based on the calibration factor. Advantageously, an alternative data collection process is provided. When the optical signals are carried out in close succession (i.e. at a frequency of at least 1Hz), the influence of background radiation is negligible. Furthermore, the reference signal also helps to reduce problems associated with temperature effects in optical measurements. This is because particular optical signals, such as visible light signals, vary with temperature and such changes will be accounted for in both the reference and fluid signals.

[0009] The calibration factor may be determined by plotting a regression line of the reference and fluid signals captured for the control fluid and dividing the known turbidity of the control fluid by the gradient of the regression line. That is, the reciprocal of the gradient of a calibration regression line plotted between the reference and fluid signals captured for the control fluid is multiplied by the known turbidity. The turbidity of the sample fluid is determined by plotting a regression line of the reference and fluid signals captured for the sample fluid and multiplying the calibration factor by the gradient of the regression line.

[0010] The turbidity sensor comprises a controller for controlling the emitter. The controller is further arranged for controlling the first and second optical detectors. The controller may control the frequency of optical signals during an optical test. The controller may comprise a memory for storing detected signals, such as a plurality of reference and fluid signals and/or other information related to the turbidity measurements, such as a calibration factor and/or the turbidity of a sample fluid. In particular, the controller is configured to store the calibration factor and to calculate the unknown turbidity of a sample fluid.

[0011] Preferably, the first and second optical detectors are photodetectors such as photodiodes. Preferably, the optical test is repeated on a plurality of sample fluids without needing to update the calibration factor. That is, the method may comprise repeating the optical test a plurality of times, wherein each time the optical test is run on a different sample fluid with unknown turbidity. Advantageously, a single control fluid can be used to measure the turbidity of a plurality of fluid samples.

[0012] Preferably, a primary optical signal is composed as part of the plurality of optical signals. That is, one of the plurality of optical signals is a primary optical signal. The remaining optical signals are non-primary optical signals. The optical setting of each non-primary optical signal may be substantially 10% to 90% of the optical setting of the primary optical signal. Alternatively, the optical setting of each non-primary optical signal may be substantially 25% to 75% of the optical setting of the primary optical signal.

[0013] According to the invention, the optical characteristic is light intensity (i.e. luminance). The light intensity may otherwise be called brightness and may be determined by the power of the emitter. The optical setting of the primary optical signal may be created at substantially full power of the emitter. The variation in light intensity may be achieved electronically or mechanically. For example, the current of the emitter may be varied or a shutter in front of the emitter may open or close to impede the amount of light that is emitted.

[0014] Preferably, the frequency of the plurality of optical signals for the optical test is at least 1Hz. Alternatively, the frequency may be at least 5Hz or at least 10Hz. That is, the time interval between optical tests for each fluid (whether control or sample) may be up to 1s, 0.2s or 0.1s. Preferably, the duration of the optical signal is around 100ms to allow good noise rejection, particularly 50/60Hz noise rejection and to give enough time for the emitter and detectors to respond. A waiting time between the end of an optical signal and the start of the proceeding optical signal may be around 10ms. The optical setting (i.e. the output intensity) may be changed during the waiting time. That is, the time interval between optical tests for each fluid may be up to 0.1s. Preferably, the time interval is between 0.01s and 0.5s. Most preferably, the time interval is between 0.05 and 0.2s. Advantageously, the close succession of optical signals allows the effect of background radiation to be ignored because any changes in background are negligible. When the tests are carried out at substantially steady state or stationary background levels, the additional effect on the optical response is constant. Background radiation is any optical source that is not from the emitter, for example ambient light.

[0015] According to the disclosure, a turbidity sensor is provided. The turbidity sensor comprises housing having an emitter and first and second optical detectors coupled to the housing. The emitter is arranged to emit a plurality of optical signals so that each optical signal has a different optical setting that is derived from a particular optical characteristic. Each of the plurality of optical signals may be emitted sequentially and at different times. The emitter may be an LED or a plurality of LEDs. The optical signal may be a collimated optical signal. The first and second optical detectors are

configured to detect a respective optical response of each optical signal. The arrangement of the first and second detectors is used to affect the optical response detected from the emitter. The first optical detector is arranged to receive the maximum optical response because the first optical detector is preferably positioned closer to the emitter than the second optical detector. Furthermore, the first optical detector is arranged to receive the optical signal before the optical signal has entered the fluid. Both the first and second optical detectors may be in indirect view of the emitter (i.e. not in line of sight). Alternatively, the first optical detector may be in direct view of the emitter (i.e. in line of sight), whereas the second optical detector may be arranged in indirect view of the emitter (i.e. not in line of sight). That is, the second optical detector may not be in the direct beam path of the emitter. This allows the second optical detector to detect the influence of the fluid on the emitted optical signal whereas the first optical detector is not influenced by the optical scatter within the fluid. The first optical detector and emitter may be sealed from the fluid by a fluid barrier. The fluid barrier may be a window, such as a sapphire window. The fluid barrier may be positioned at an outlet of a collimating tube, wherein the emitter is interposed between the tube outlet and the first optical detector.

[0016] The turbidity sensor comprises a controller arranged to control the emitter. The controller is further arranged to control the first and second optical detectors. The controller may control the frequency of optical signals during an optical test. The controller may comprise a memory to store detected signals, such as a plurality of reference and fluid signals and/or other information related to the turbidity measurements, such as a calibration factor and/or the turbidity of a sample fluid. In particular, the controller is configured to store the calibration factor and to calculate the unknown turbidity of a sample fluid.

[0017] The turbidity sensor is a probe that emits and detects optical signals. The turbidity sensor may generally be an elongate member. One end of the turbidity sensor may comprise the two detectors and the emitter. The second optical detector may be located at a tip of the housing, which is a substantially distal location of the turbidity sensor.

[0018] The turbidity sensor may comprise a blocking member for blocking a direct line of incidence from the emitter to the second optical detector. The blocking member may be disposed between the first and second optical detectors. The housing may comprise a step (i.e. a stepped portion) which acts as the blocking member.

[0019] The first and second detectors may face in substantially the same direction as each other. The second detector may be arranged at substantially 90 degrees to a main line of incidence from the emitter. The second detector may be arranged anywhere between 90 degrees and 180 degrees to a main line of incidence from the emitter. Alternatively, the second detector may be arranged at substantially 135 degrees or 180 degrees (between 135 degrees and 180 degrees) to a main line of incidence from the emitter. That is, the angle between the direction that the first and second detectors face may be separated by an angle between 45 degrees or 90 degrees.

[0020] The turbidity sensor may comprise a collimating member for collimating the optical signal from the emitter. The collimating member may be a collimating tube. The housing may have a recess within which the collimating tube exists. The first optical detector and emitter may be located within the recess.

[0021] The turbidity sensor may be configured to be submerged in a liquid and prevent liquid ingress to electrical components. The turbidity sensor may therefore comprise sealing members for preventing the ingress of liquid beyond the emitter and the first and second optical detectors and into the housing when the turbidity sensor is submerged in liquid.

[0022] Beneficially, an alternative solution to accurately collecting turbidity measurements is provided. The turbidity sensor and method removes the effect of background noise to utilise a single calibration so that a plurality of turbidity measurements can be taken without needing to recalibrate the turbidity sensor. The alternative approach is more convenient whilst maintaining high accuracy. The disclosure herein is more convenient to a user and provides a better solution over conventional apparatuses and method.

BRIEF DESCRIPTION OF DRAWINGS

[0023] For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which:

Figure 1 shows a turbidity sensor of the present disclosure;

Figure 2 shows a cross-sectional view of the turbidity sensor of Figure 1;

Figure 3 shows a flow chart of the data collection process using the optical sensor of Figure 1;

Figure 4 shows a calibration graph for the turbidity sensor when using a 10 NTU calibration sample with four optical tests from 25% to 100% power;

Figure 5 shows calibration graphs for the turbidity sensor when using calibration samples having high turbidity (from 5 NTU to 50 NTU) each with two optical tests at 50% and 100% power;

Figure 6 shows calibration graphs for the turbidity sensor when using calibration samples having low turbidity (from 0.33 NTU to 3 NTU) each with two optical tests at 50% and 100% power;

Figure 7 shows the near-linear relationship between the gradient of the calibration lines of Figures 4 and 5 with the actual turbidity of the calibration samples;

Figure 8 shows a comparison between the low turbidity readings (from 0.1 NTU to 0.7 NTU) captured by the turbidity sensor with the actual turbidity of the calibration samples; and

Figure 9 shows a comparison between the high turbidity readings (from 10 NTU to 184 NTU) captured by the turbidity sensor with the actual turbidity of the calibration samples.

DESCRIPTION OF EMBODIMENTS

[0024] Figures 1 and 2 show a turbidity sensor 100 comprising an emitter 10, a first optical detector 20 and a second optical detector 30 that are each coupled to a housing 40. The first optical detector 20 is located closer to the emitter 10 than the second optical detector 30 in order to measure the actual output of the emitter 10. The first optical detector 20 is shown in direct line of sight of the emitter 10 and is held within a hole in the wall of housing 40 by adhesive. In the example shown, the second optical detector 30 is positioned at a tip 48 of the housing 40 and at a relative angle θ of 90° (i.e. 90 degrees). That is, the relative angle θ is the angle between the central line of the detector and the main line of incidence L of the optical signal from the emitter 10. Once the optical signal from the emitter 10 has exited the housing 40, the optical signal enters a fluid and scatters within the fluid due to the fluid particles. The second optical detector 30 then detects the amount of scatter within the fluid. It is therefore important that the second optical detector 30 is not in the line of sight of the emitter 10 because the second optical detector 30 should not detect direct optical signals from the emitter 10. Conveniently, a blocking means, such as a stepped portion 46 is provided to prevent the direct signals being transferred from the emitter 10 to the second optical detector 30. However, the edge of an opening 52 to the emitter 10 may be used as the blocking means when the emitter is recessed into the housing 40. In the example shown, a plurality of blocking means is used to minimise the impact of incident optical signals from the emitter. The opening 52 may be a fluid barrier that prevents fluid entry. For example, the fluid barrier may be a sapphire window that allows an optical signal to pass but does not allow fluid to pass.

[0025] The emitter 10 is configured to emit light from the housing 40 by passing the light through a collimating member, such as a collimating tube 50. When a fluid barrier is used, the emitter 10 and first detector 20 may be on the 'dry' side, i.e. the side that does not contact the test fluid because the fluid cannot pass the fluid barrier. The light may be visible light or may be light that is invisible to the human eye, such as near-infrared light (i.e. light having a wavelength of around 850nm to 860nm). The light is then used to illuminate a fluid within which the turbidity sensor 100 is immersed (or at least the emitter 10 and detectors 20,30). The collimating tube 50 helps to collimate the emitted light from the housing 40 (e.g. align the optical signal in a parallel manner). Although the housing 40 shows the emitter 10 contained within the collimating tube 50, the emitter 10 and collimating tube 50 may both be contained within a recess within the housing 40. The second optical detector 20 may therefore receive optical signals from within the recess and/or the collimating tube 50.

[0026] In the example shown, the housing 40 is shown in two parts. The first part is a head 42 and the second is a base 44. The head 42 may be removable from the base 44 by so that the base 44 can be interchangeable with a variety of different heads. Each head 42 may comprise a different relative angle θ so that the second optical detector 30 may receive scattered signals at different positions. For example, relative angles θ of 135° or 180° may be used. The head 42 and base 44 may be coupled by the use of a fastening means such as a screw and thread. The fastening means may comprise a sealing member to prevent fluid ingress when the turbidity sensor is submersed in a fluid.

[0027] Figure 3 shows a data collection method 200 using the optical sensor 100. The method 200 does not require the calculation of the background noise, such as background light, which means that calibrating the turbidity sensor 100 does not need to occur with every signal if a calibration factor has been calculated.

[0028] The method 200 starts by providing a control fluid (as shown in the left-hand box with dashed lines), which is used as a calibration sample. The turbidity sensor 100 is placed within the control fluid so that an optical test can be conducted 210. To start the first optical test 210, the optical setting of the turbidity sensor 100 is set 211. For example, the emitter 10 may be set to emit a light signal at full (i.e. 100%) power. Once the optical signal is emitted towards the fluid 212, the first 20 and second 30 detectors capture the optical response. Being in direct view (i.e. in the line of sight) of the emitter 10, the first optical detector 20 receives a strong signal from the emitter 10, which is considered to be the actual or reference optical signal. The reference signal is then captured 213 by the first detector 20. Simultaneously, a fluid signal is captured 214 by the second optical detector 30. Since the second optical detector 30 is not in direct view of the emitter 10 (i.e. in indirect view or out of the line of sight), this fluid signal is weaker than the reference signal. The detected optical signals are then recorded for later use to complete the first optical test.

[0029] Once the first optical test 210 is completed, a second optical test 210 is run. Preferably, the time between each optical test does not exceed 1s which allows a minimum frequency between optical tests of around 1hz. Most preferably the maximum time is around 0.2s (giving a frequency of around 5Hz). A minimum of two optical tests must be run in order to calibrate the turbidity sensor 100 according to the control sample. The second optical test 210 is run at reduced power so that the emitter 10 sends an optical signal with lower intensity than the first optical test 210. For example, the light signal may be reduced to 75%, 50% or 25% power. Once again, the reference and fluid signals detected by the first 20 and second 30 optical detectors respectively are captured and recorded. The measured signals are then plotted against each other.

[0030] Figure 4 shows the results obtained by illuminating a 10 NTU control (i.e. calibration) sample with an LED (light emitting diode) emitting near-infrared light at a wavelength of around 860nm and measuring the light detected at a photodiode (i.e. the second optical detector 30) positioned at a relative angle θ of 90° (i.e. the angle from the incident light). The fluid and reference signals were collected when running four optical tests (25%, 50%, 75% and 100% power of the emitter 10). The results are shown in ascending order of power and the current of the fluid and reference signals are shown in nA. A highly accurate regression line can be plotted between the plurality of points because the relationship is near linear. The slope of the regression line is then calculated to produce the calibration factor 216 using the following equation:

$$\text{Calibration Factor} = \text{Sample Turbidity} / \text{Gradient} \quad \text{Equation (1)}$$

[0031] The calibration factor (or gain) based on the 10 NTU sample is 8333.33 (10 NTU / 0.0012).

[0032] The regression line of Figure 4 would continue to intersect the y-axis at near zero. This relationship is shown when collecting samples from high and low level turbidity control samples as shown in Figures 5 and 6, respectively. In contrast to Figure 4, each optical test 210 was run at only 50% and 100% power of the emitter 10. The regression lines plotted for each control sample show that the gradient changes with turbidity. In fact, the relationship is highly linear and the gradient appears to be directly proportional to turbidity, as shown in Figure 7. Here, the gradients calculated from the high and low optical tests 210 are plotted against the turbidity of each control sample. The coefficient of determination (R^2) of the resulting regression line is 0.999.

[0033] As further shown in Figure 3, the method 200 further includes repeating the optical test for a sample fluid 220 to calculate the turbidity of the sample fluid 226 using the calibration factor previously obtained 216 (as shown in the right-hand box with dashed lines). As with the control sample, the optical test begins with providing a sample fluid within which the turbidity sensor 100 is submersed. A plurality of optical signals are then sent into the sample fluid from the emitter 10 and each time a reference 223 and fluid signal 224 is captured. Once all the tests are run 225, the reference and fluid signals are plotted for each optical test and the gradient resulting from the regression line is calculated. A rearranged version of Equation (1) is then used to calculate the turbidity of the sample fluid:

$$\text{Sample Turbidity} = \text{Calibration Factor} \times \text{Gradient} \quad \text{Equation (2)}$$

[0034] The results for measuring low and high levels of turbidity (0.1 to 184 NTU) with a turbidity sensor calibrated using a 10 NTU sample are shown in Figures 8 and 9, whereby a coefficient of determination (R^2) for each graph is at least 0.999.

[0035] The turbidity sensor 100 and method 200 uses an alternative approach of calculating turbidity. The method 200 allows for simple calibration and gives stable results. In summary, the method 200 involves taking measurements at different light levels in very close succession (the frequency of the optical tests will be at least 1Hz, 5Hz or 10Hz). This means that a calibration can be carried out using a single sample because varying the light output results in a relationship between turbidity and the detected signal. This avoids the influence of changes in background light levels. The gradient of a regression line plotted for the plurality of readings captured during the optical test by the first 20 and second 30 detectors is then used to determine the sample turbidity when a calibration factor is known. Since the optical tests are taken in rapid succession, the influence of the background is negligible because the background can be assumed to be stationary. This means that the gradient is not affected by the background and true readings of turbidity can be obtained.

[0036] Advantageously, an improved turbidity sensor 100 and method for measuring turbidity is provided. The improved turbidity sensor 100 and method produces accurate turbidity measurements across a wide range of samples. Beneficially, only a single calibration sample is needed to calibrate the turbidity sensor 100 because the background radiation can be ignored. Overall, a better optical sensor 100 and method for measuring turbidity is provided that solves the drawbacks associated with conventional turbidity sensors and methods.

[0037] Although preferred embodiment(s) of the present invention have been shown and described, it will be appreciated

ciated by those skilled in the art that changes may be made without departing from the scope of the invention as defined in the claims.

5 Claims

1. A method of measuring turbidity with a nephelometric turbidity sensor (100), the method comprising conducting an optical test on a sample fluid with unknown turbidity, wherein the optical test comprises:

10 emitting a plurality of optical signals in sequence from an emitter (10) toward the fluid, each of the optical signals having a different intensity setting:

capturing, for each of the optical signals, a reference signal value by detecting an intensity of the optical signal received by a first optical detector before entering the fluid, and a fluid signal value by detecting an intensity of the optical signal received by a second optical detector after entering the fluid;

15 the method further comprising conducting the optical test on a control fluid with known turbidity to determine a calibration factor; and

determining a turbidity measurement of the sample fluid by calculating a gradient of a regression line between the reference signal values and fluid signal values for each of the plurality of optical signals, wherein the gradient of the regression line is proportional to turbidity of the sample fluid, and

20 multiplying the gradient of the regression line by the calibration factor to provide a calibrated turbidity measurement.

2. The method of claim 1, wherein the plurality of optical signals comprises a primary optical signal at or about a full power of the emitter (10) and one or more non-primary optical signals having an intensity which is less than the primary optical signal, preferably being 10% to 90% of the primary optical signal, and more preferably 25% to 75% of the primary optical signal.

3. The method of any preceding claim, wherein the plurality of optical signals are output with a frequency of at least 1 Hz, whereby the plurality of optical signals are output in succession within one second.

4. The method of any preceding claim, wherein each of the optical signals has a duration of about 100 ms.

5. The method of any preceding claim, wherein the optical signals are separated in succession by a period of about 10 ms.

6. A nephelometric turbidity sensor (100), comprising

a housing (40);

an emitter (10) for emitting optical signals toward a sample fluid;

40 first and second optical detectors (20, 30), wherein the first optical detector (20) is arranged to receive the optical signal before entering the sample fluid and the second optical detector (30) is arranged to receive the optical signal after entering the sample fluid;

wherein the emitter (10) and the first and second optical detectors (20, 30) are coupled to the housing (40);

45 and wherein the sensor further comprises a controller configured to conduct an optical test by measuring turbidity of the sample fluid by:

causing the emitter (10) to output a plurality of optical signals in succession toward the sample fluid, each of the optical signals having a different intensity setting;

50 capturing, for each of the optical signals, a reference signal value from the first optical detector (20) before entering the sample fluid and a fluid signal value from the second optical detector (30) after entering the sample fluid; and

determining a turbidity measurement of the sample fluid by calculating a gradient of a regression line between the reference and fluid signal values for each of the plurality of optical signals,

55 wherein the controller is configured to determine a calibration factor of a control fluid with known turbidity by causing the sensor (100) to conduct the optical test on the control fluid and to store the determined calibration factor; and

wherein the controller is configured to provide a calibrated turbidity measurement by multiplying the gradient of the regression line by the calibration factor.

7. The sensor of claim 6, further comprising a blocking member (46, 52) configured to block a direct line of incidence from the emitter (10) to the second optical detector (30).
8. The sensor of claim 7, wherein the blocking member (46, 52) is disposed between the first and second optical detectors (20, 30).
9. The sensor of any of claims 6 to 8, wherein the housing (40) comprises a step (46) which acts as the blocking member.
10. The sensor of any of claims 6 to 9, wherein the second optical detector (30) is arranged at substantially 90 degrees to a main line of incidence from the emitter (10).
11. The sensor of any of claims 6 to 10, further comprising a collimating member (50) configured to collimate the optical signal from the emitter (10).
12. The sensor of any of claims 7 to 11, having a plurality of removable and interchangeable head portions (42) which are each configured with a different relative angle between the emitter (10) and the second optical detector (30).
13. Use of the sensor of any of claims 6 to 12 to perform the method of any of claims 1 to 5.

Patentansprüche

1. Verfahren zum Messen von Trübung mit einem nephelometrischen Trübungssensor (100), wobei das Verfahren umfasst, einen optischen Test an einer Probenflüssigkeit mit unbekannter Trübung durchzuführen, wobei der optische Test umfasst:
 Aussenden mehrerer optischer Signale nacheinander von einem Emittor (10) in Richtung der Flüssigkeit, wobei jedes der optischen Signale eine andere Intensitätseinstellung hat,
 Erfassen, für jedes der optischen Signale, eines Referenzsignalwertes durch Erfassen einer Intensität des optischen Signals, das durch einen ersten optischen Detektor vor dem Eintritt in die Flüssigkeit empfangen wird, und eines Flüssigkeitssignalwertes durch Erfassen einer Intensität des optischen Signals, das durch einen zweiten optischen Detektor nach dem Eintritt in die Flüssigkeit empfangen wird;
 wobei das Verfahren ferner umfasst, den optischen Test an einer Kontrollflüssigkeit mit bekannter Trübung durchzuführen, um einen Kalibrierungsfaktor zu bestimmen; und
 Bestimmen einer Trübungsmessung der Probenflüssigkeit, indem ein Gradient einer Regressionslinie zwischen den Referenzsignalwerten und den Flüssigkeitssignalwerten für jedes der mehreren optischen Signale berechnet wird, wobei der Gradient der Regressionslinie proportional zur Trübung der Probenflüssigkeit ist, und
 Multiplizieren des Gradienten der Regressionslinie mit dem Kalibrierungsfaktor, um eine kalibrierte Trübungsmessung zu erhalten.
2. Verfahren nach Anspruch 1, wobei die mehreren optischen Signale ein primäres optisches Signal mit der oder ungefähr der vollen Leistung des Emittors (10) und ein oder mehrere nicht primäre optische Signale mit einer Intensität umfassen, die geringer als das primäre optische Signal ist, vorzugsweise 10 % bis 90 % des primären optischen Signals und noch stärker bevorzugt 25 % bis 75 % des primären optischen Signals.
3. Verfahren nach einem der vorstehenden Ansprüche, wobei die mehreren optischen Signale mit einer Frequenz von wenigstens 1 Hz ausgegeben werden, wodurch die mehreren optischen Signale innerhalb einer Sekunde nacheinander ausgegeben werden.
4. Verfahren nach einem der vorstehenden Ansprüche, wobei jedes der optischen Signale eine Dauer von ungefähr 100 ms hat.
5. Verfahren nach einem der vorstehenden Ansprüche, wobei die optischen Signale in ihrer Abfolge durch einen Zwischenraum von ungefähr 10 ms voneinander getrennt sind.
6. Nephelometrischer Trübungssensor (100), umfassend:
 ein Gehäuse (40);

einen Emitter (10) zum Aussenden von optischen Signalen in Richtung einer Probenflüssigkeit;
einen ersten und einen zweiten optischen Detektor (20, 30), wobei der erste optische Detektor (20) dafür
ausgelegt ist, das optische Signal vor dem Eintritt in die Probenflüssigkeit zu empfangen, und der zweite optische
Detektor (30) dafür ausgelegt ist, das optische Signal nach dem Eintritt in die Probenflüssigkeit zu empfangen;
wobei der Emitter (10) und der erste und zweite optische Detektor (20, 30) mit dem Gehäuse (40) gekoppelt sind;
und wobei der Sensor ferner umfasst:
eine Steuerung, die dafür ausgelegt ist, einen optischen Test durch Messen der Trübung der Probenflüssigkeit
durchzuführen durch:

Veranlassen des Emitters (10), mehrere optische Signale nacheinander in Richtung der Probenflüssigkeit
auszugeben, wobei jedes der optischen Signale eine andere Intensitätseinstellung hat;
Erfassen, für jedes der optischen Signale, eines Referenzsignalwertes vom ersten optischen Detektor (20)
vor dem Eintritt in die Probenflüssigkeit und eines Flüssigkeitssignalwertes vom zweiten optischen Detektor
(30) nach dem Eintritt in die Probenflüssigkeit; und
Bestimmen einer Trübungsmessung der Probenflüssigkeit, indem ein Gradient einer Regressionslinie zwi-
schen dem Referenz- und dem Flüssigkeitssignalwert für jedes der mehreren optischen Signale berechnet
wird,
wobei die Steuerung dafür ausgelegt ist, einen Kalibrierungsfaktor einer Kontrollflüssigkeit mit bekannter
Trübung zu bestimmen, indem sie den Sensor (100) veranlasst, den optischen Test an der Kontrollflüssigkeit
durchzuführen und den bestimmten Kalibrierungsfaktor zu speichern; und
wobei die Steuerung dafür ausgelegt ist, eine kalibrierte Trübungsmessung durch Multiplizieren des Gra-
dienten der Regressionslinie mit dem Kalibrierungsfaktor bereitzustellen.

7. Sensor nach Anspruch 6,
ferner ein Sperrelement (46, 52) umfassend, das dafür ausgelegt ist, eine direkte Einfallslinie vom Emitter (10) zum
zweiten optischen Detektor (30) zu versperren.
8. Sensor nach Anspruch 7,
wobei das Sperrelement (46, 52) zwischen dem ersten und dem zweiten optischen Detektor (20, 30) angeordnet ist.
9. Sensor nach einem der Ansprüche 6 bis 8,
wobei das Gehäuse (40) eine Stufe (46) aufweist, die als Sperrelement dient.
10. Sensor nach einem der Ansprüche 6 bis 9,
wobei der zweite optische Detektor (30) im Wesentlichen in einem Winkel von 90 Grad zu einer Haupteinfallslinie
vom Emitter (10) angeordnet ist.
11. Sensor nach einem der Ansprüche 6 bis 10,
ferner ein Kollimationselement (50) umfassend, das dafür ausgelegt ist, das optische Signal des Emitters (10) zu
kollimieren.
12. Sensor nach einem der Ansprüche 7 bis 11,
mehrere abnehmbare und austauschbare Kopfteile (42) aufweisend, die jeweils mit einem anderen relativen Winkel
zwischen dem Emitter (10) und dem zweiten optischen Detektor (30) ausgestaltet sind.
13. Verwendung des Sensors nach einem der Ansprüche 6 bis 12 zum Durchführen des Verfahrens nach einem der
Ansprüche 1 bis 5.

Revendications

1. Procédé de mesure de turbidité à l'aide d'un capteur de turbidité néphélométrique (100), le procédé comprenant la
réalisation d'un test optique sur un fluide échantillon ayant une turbidité inconnue, dans lequel le test optique
comprend :

l'émission d'une pluralité de signaux optiques en séquence depuis un émetteur (10) vers le fluide, chacun des
signaux optiques ayant un réglage d'intensité différent,
la capture, pour chacun des signaux optiques, d'une valeur de signal de référence par détection d'une intensité

du signal optique reçu par un premier détecteur optique avant qu'il pénètre dans le fluide, et d'une valeur de signal de fluide par détection d'une intensité du signal optique reçu par un second détecteur optique après qu'il a pénétré dans le fluide ;

le procédé comprenant en outre la réalisation du test optique sur un fluide témoin ayant une turbidité connue afin de déterminer un facteur d'étalonnage ; et

la détermination d'une mesure de turbidité du fluide échantillon par calcul du gradient d'une droite de régression entre les valeurs du signal de référence et les valeurs du signal de fluide pour chacun de la pluralité de signaux optiques, dans lequel le gradient de la droite de régression est proportionnel à la turbidité du fluide échantillon, et la multiplication de la pente de la droite de régression par le facteur d'étalonnage pour obtenir une mesure de turbidité étalonée.

2. Procédé selon la revendication 1, dans lequel la pluralité de signaux optiques comprend un signal optique primaire à ou approximativement à la puissance maximale de l'émetteur (10) et un ou plusieurs signaux optiques non primaires ayant une intensité inférieure à celle du signal optique primaire, de préférence de 10% à 90% du signal optique primaire, et plus préférentiellement de 25% à 75% du signal optique primaire.

3. Procédé selon l'une quelconque des revendications précédentes, dans lequel la pluralité de signaux optiques sont délivrés à une fréquence d'au moins 1 Hz, la pluralité de signaux optiques étant délivrés successivement en moins d'une seconde.

4. Procédé selon l'une quelconque des revendications précédentes, dans lequel chacun des signaux optiques a une durée d'environ 100 ms.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel les signaux optiques sont séparés successivement d'une période d'environ 10 ms.

6. Capteur de turbidité néphélométrique (100), comprenant un boîtier (40) ;

un émetteur (10) pour émettre des signaux optiques vers un fluide échantillon ;
des premier et second détecteurs optiques (20, 30), dans lequel le premier détecteur optique (20) est agencé pour recevoir le signal optique avant qu'il pénètre dans le fluide échantillon et le second détecteur optique (30) est agencé pour recevoir le signal optique après qu'il a pénétré dans le fluide échantillon ;
dans lequel l'émetteur (10) et les premier et second détecteurs optiques (20, 30) sont couplés au boîtier (40) ;
et dans lequel

le capteur comprend en outre un dispositif de commande configuré pour réaliser un test optique par mesure de la turbidité du fluide échantillon par :

le fait d'amener l'émetteur (10) à délivrer une pluralité de signaux optiques successifs vers le fluide échantillon, chacun des signaux optiques ayant un réglage d'intensité différent ;

la capture, pour chacun des signaux optiques, d'une valeur de signal de référence à partir du premier détecteur optique (20) avant qu'il pénètre dans le fluide échantillon et d'une valeur de signal de fluide à partir du second détecteur optique (30) après qu'il a pénétré dans le fluide échantillon ; et

la détermination d'une mesure de turbidité du fluide échantillon par calcul du gradient d'une droite de régression entre les valeurs du signal de référence et du signal de liquide pour chacun des signaux optiques, dans lequel le dispositif de commande est configuré pour déterminer un facteur d'étalonnage d'un fluide témoin ayant une turbidité connue en amenant le capteur (100) à réaliser le test optique sur le fluide témoin et à stocker le facteur d'étalonnage déterminé ; et

dans lequel le dispositif de commande est configuré pour fournir une mesure de turbidité étalonée par multiplication du gradient de la droite de régression par le facteur d'étalonnage.

7. Capteur selon la revendication 6, comprenant en outre un élément de blocage (46, 52) configuré pour bloquer une droite d'incidence directe allant de l'émetteur (10) au second détecteur optique (30).

8. Capteur selon la revendication 7, dans lequel l'élément de blocage (46, 52) est disposé entre les premier et second détecteurs optiques (20, 30).

9. Capteur selon l'une quelconque des revendications 6 à 8, dans lequel le boîtier (40) comprend une marche (46) qui agit comme un élément de blocage.

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10. Capteur selon l'une quelconque des revendications 6 à 9, dans lequel le second détecteur optique (30) est disposé à sensiblement 90 degrés par rapport à la droite d'incidence principale partant de l'émetteur (10).
- 5 11. Capteur selon l'une quelconque des revendications 6 à 10, comprenant en outre un élément de collimation (50) configuré pour collimater le signal optique provenant de l'émetteur (10).
- 10 12. Capteur selon l'une quelconque des revendications 7 à 11, comportant plusieurs parties de tête amovibles et interchangeables (42) qui sont chacune configurées avec un angle relatif différent entre l'émetteur (10) et le second détecteur optique (30).
13. Utilisation du capteur selon l'une quelconque des revendications 6 à 12 pour mettre en œuvre le procédé selon l'une quelconque des revendications 1 à 5.

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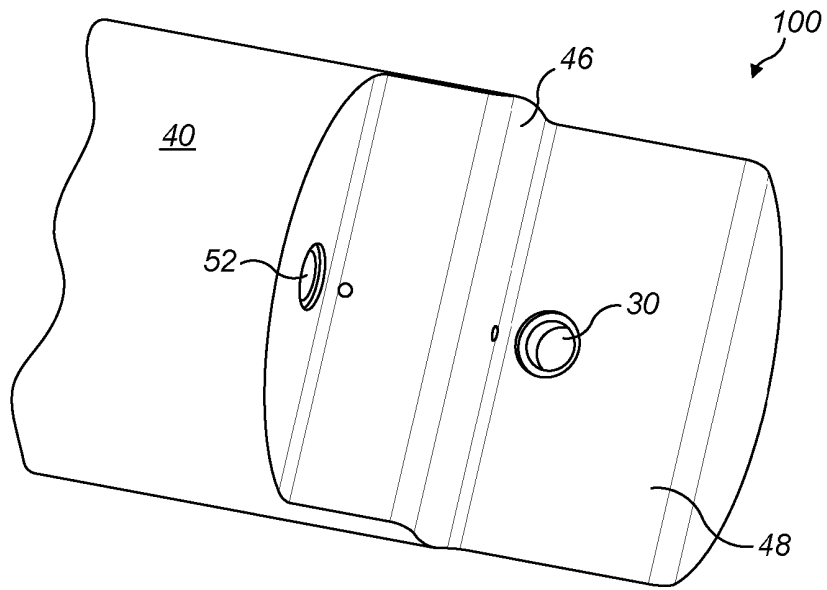


FIG. 1

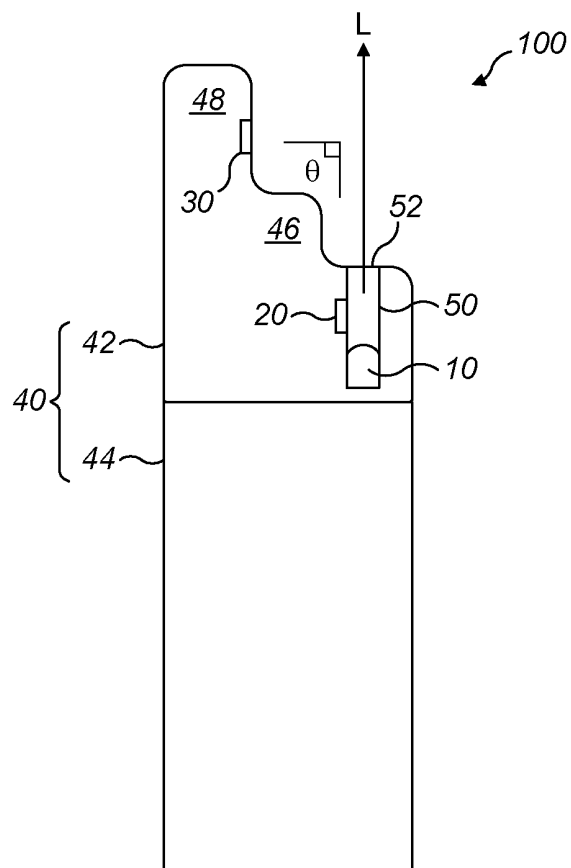


FIG. 2

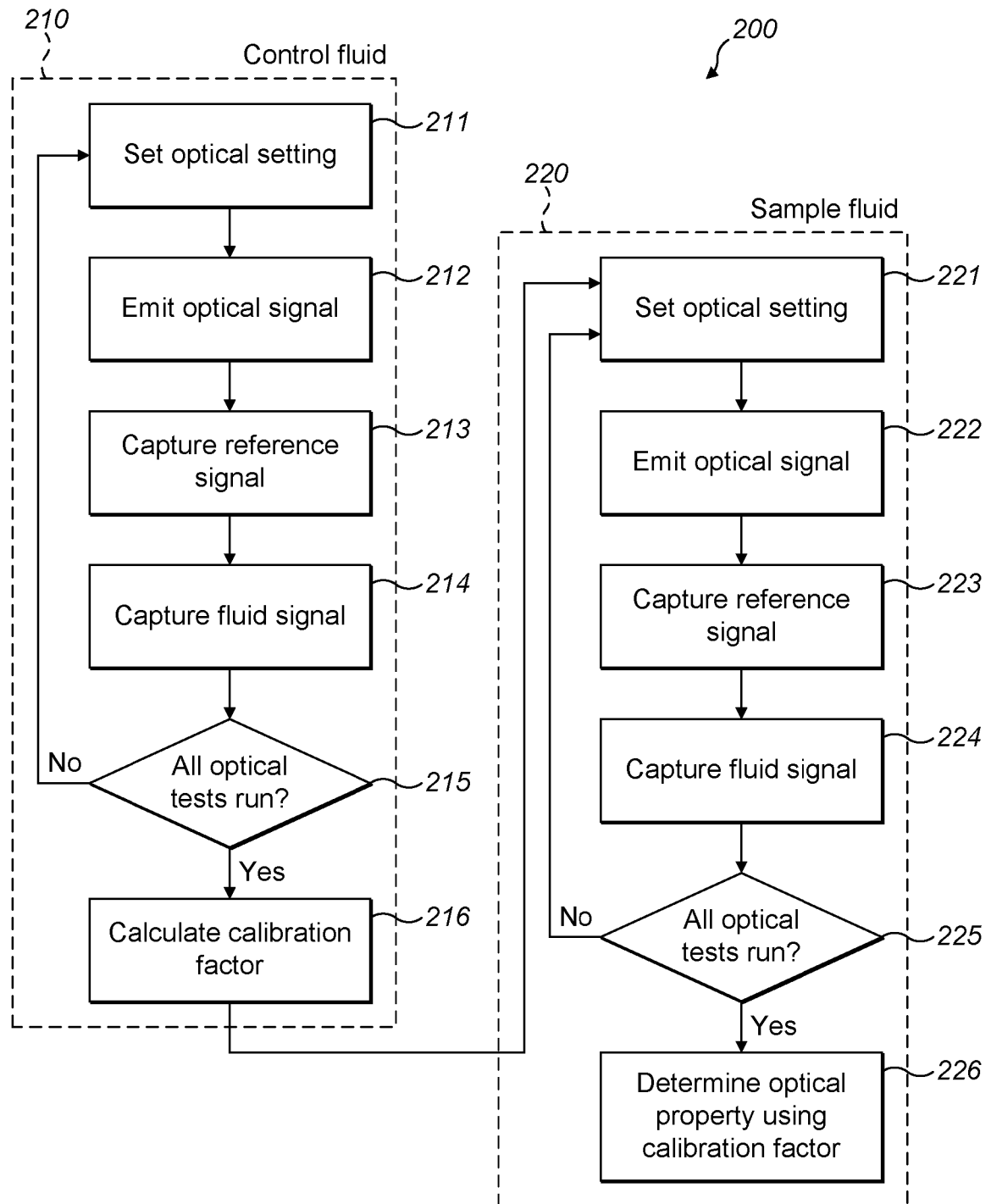


FIG. 3

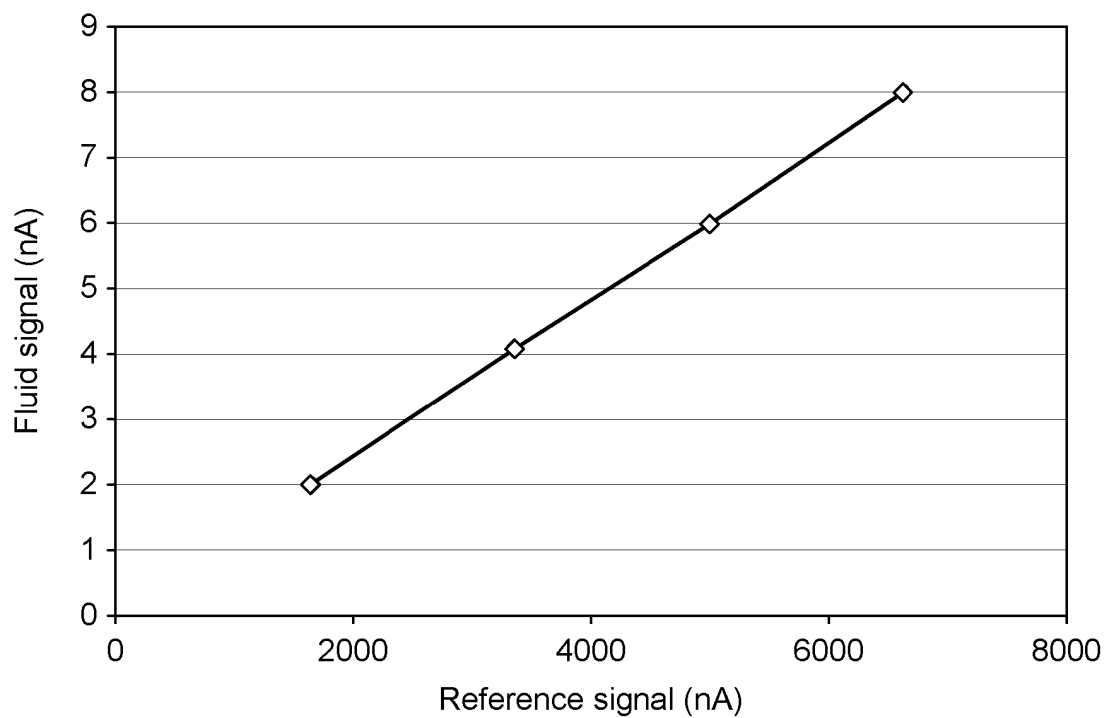


FIG. 4

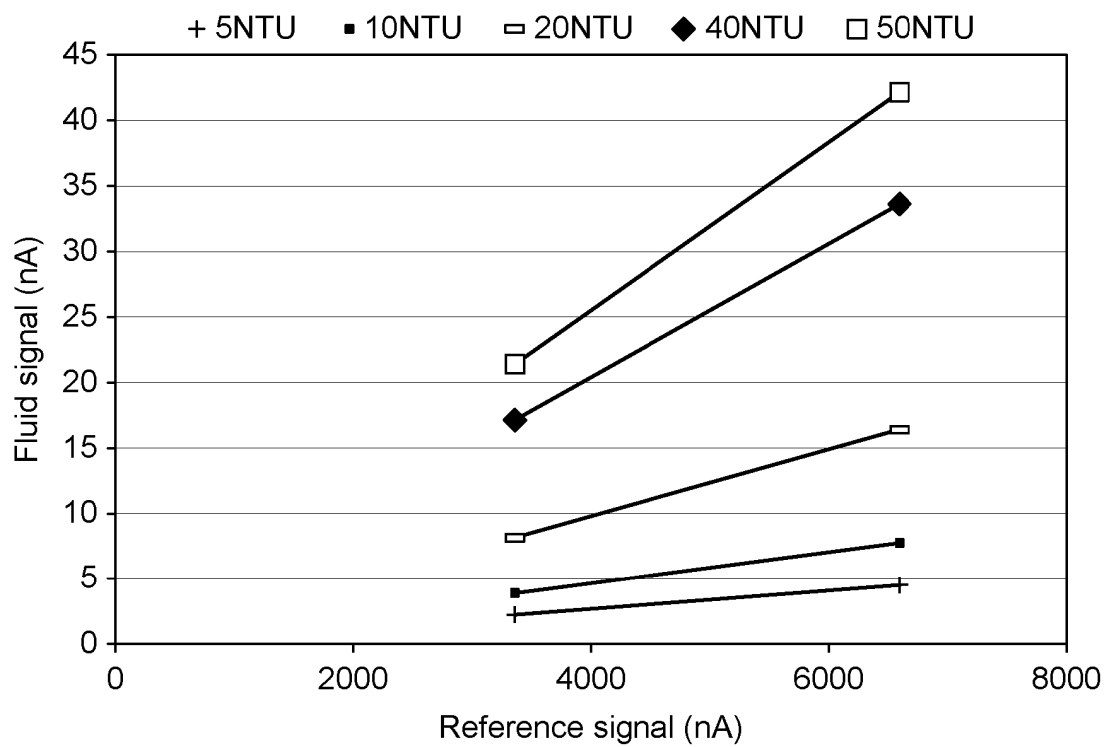


FIG. 5

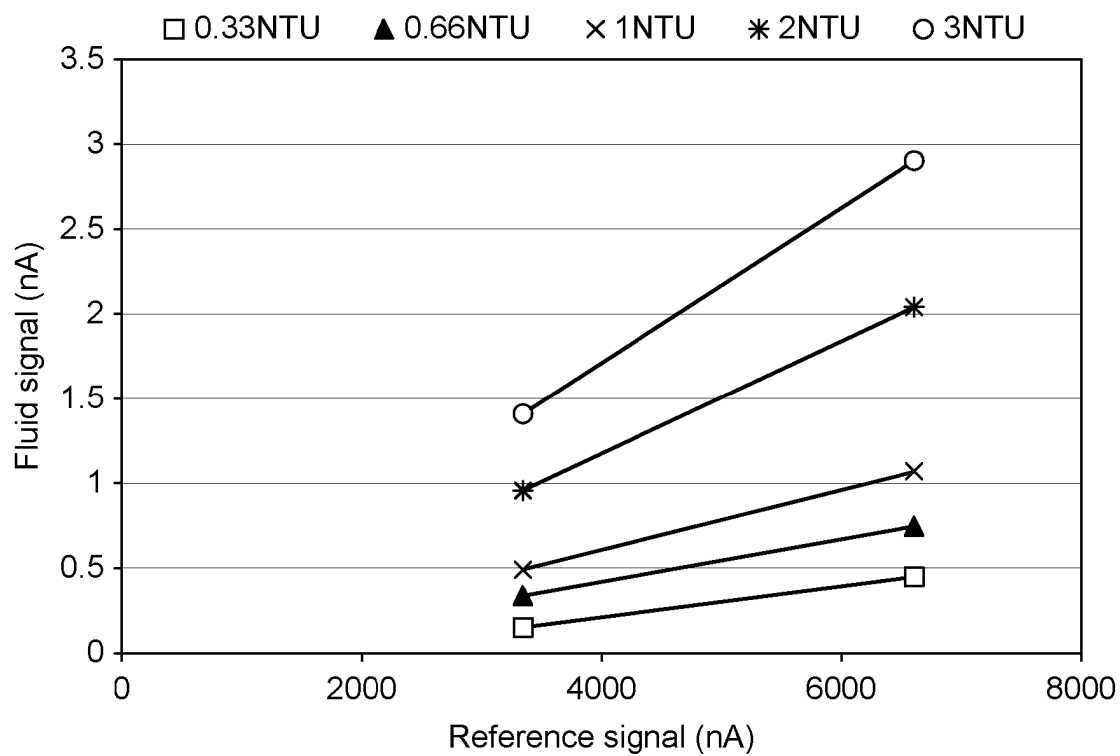


FIG. 6

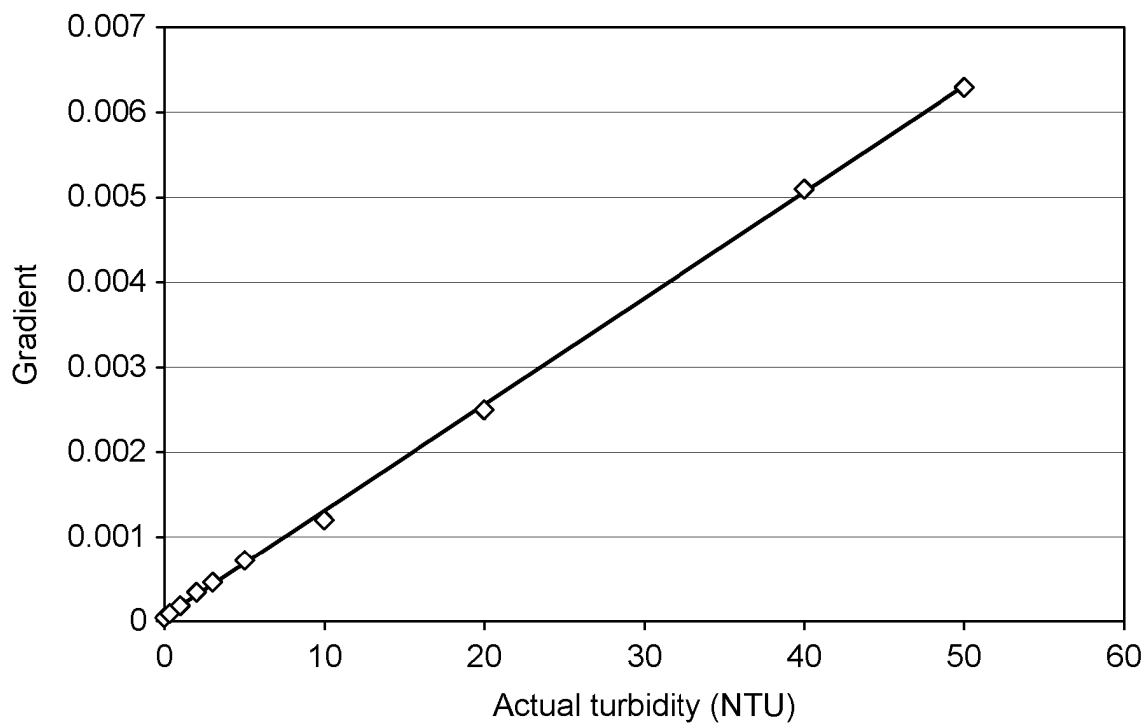


FIG. 7

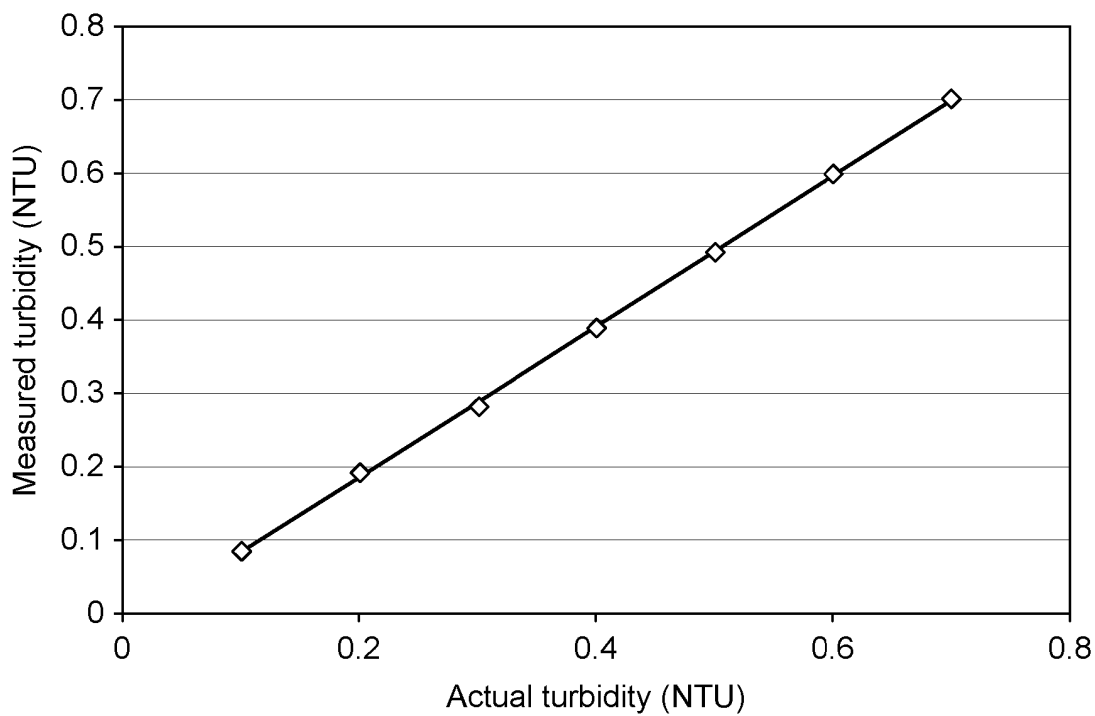


FIG. 8

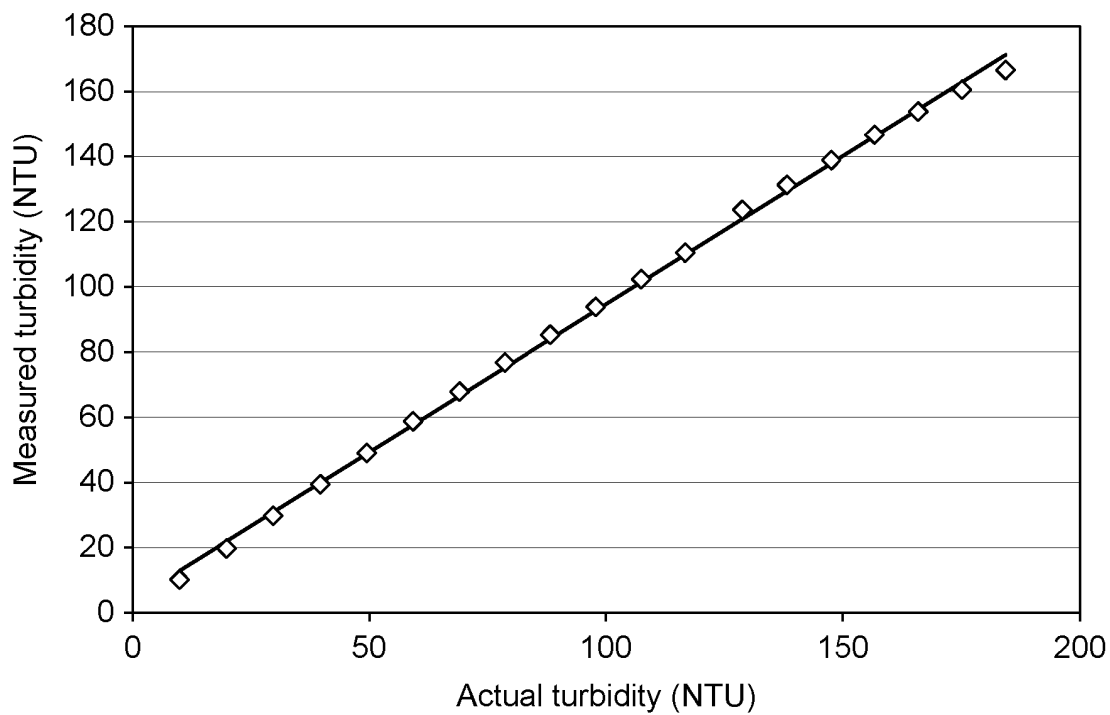


FIG. 9

REFERENCES CITED IN THE DESCRIPTION

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